

A new species of *Amphipyra* OCHSENHEIMER, 1816 from Taiwan, with description of larva, pupa and biology (Lepidoptera, Noctuidae, Amphipyrinae)¹

Mei-Yu CHEN, Wolfgang SPEIDEL, Ulf BUCHSBAUM and Gottfried BEHOUNEK

Mei-Yu CHEN, Zoologische Staatssammlung München, Münchhausenstrasse 21, D-81247 München, Germany; chen@zsm.mwn.de

Dr. Wolfgang SPEIDEL, Zoologische Staatssammlung München, Münchhausenstrasse 21, D-81247 München; speidel@zsm.mwn.de

Ulf BUCHSBAUM, Zoologische Staatssammlung München, Münchhausenstrasse 21, D-81247 München, Germany; ulfbuchsbaum.lepidoptera@zsm.mwn.de

Gottfried BEHOUNEK, Sudetenstrasse 6, D-85567 Grafing, Germany; gottfried.behounek@t-online.de

Abstract: The new species *Amphipyra meifengensis* sp. n. (holotype female, in National Museum of Natural Science Taiwan, Taichung, belonging to the species-group of *A. pyramidea* (LINNAEUS, 1758)) is described from Meifeng in the central high mountains of Taiwan. A larva of the new species was found and successfully reared so that information on the biology and morphology of larva and pupa could be added. All hitherto known *Amphipyra*-species, especially those known from Taiwan, can be easily discriminated from this new species.

Key words: Lepidoptera, Noctuidae, Amphipyrinae, *Amphipyra meifengensis* sp. n., Taiwan, biology, foodplants, distribution, mtDNA, COI.

Eine neue Art von *Amphipyra* OCHSENHEIMER, 1816 aus Taiwan, mit Beschreibung von Raupe, Puppe und Biologie (Lepidoptera, Noctuidae, Amphipyrinae)

Zusammenfassung: Die neue Art *Amphipyra meifengensis* sp. n. (Holotypus Weibchen, im National Museum of Natural Science Taiwan, Taichung, gehört zur Artengruppe von *A. pyramidea* (LINNAEUS, 1758)) wird aus Meifeng im zentralen Hochgebirge von Taiwan beschrieben. Eine Raupe wurde gefunden und durchgezüchtet, so daß Informationen zur Biologie sowie der Raupen- und Puppenmorphologie gegeben werden können. Sämtliche bekannten *Amphipyra*-Arten, insbesondere die aus Taiwan, unterscheiden sich deutlich von der vorliegenden neuen Art.

Introduction

Numerous research trips were undertaken for the German Academic Exchange Service (DAAD) project of the Bavarian State Collection of Zoology and the National Chung Hsing University Taichung (CHU) (Project No.: ID D/0039914, PPP-Taiwan), and additional cooperative projects (e.g. with the Highland Experimental Farm Meifeng) were undertaken in order to study the lepidopterous fauna of Taiwan. Many different localities were studied during this project, with Meifeng being the most frequent collecting site. Several papers about the Lepidoptera observed during these trips have already been published. In Meifeng especially, several species have been identified as undescribed or recorded as new for Taiwan, and many interesting biological observations have been published from this locality (e.g., BUCHSBAUM & MILLER 2002, SCHINTLMEISTER 2003, SPEIDEL & BEHOUNEK 2005, BUCHSBAUM 2006, BUCHSBAUM et al. 2006, BUCHSBAUM & CHEN 2010, 2012, CHEN 2010, SCHACHT et al. 2010).

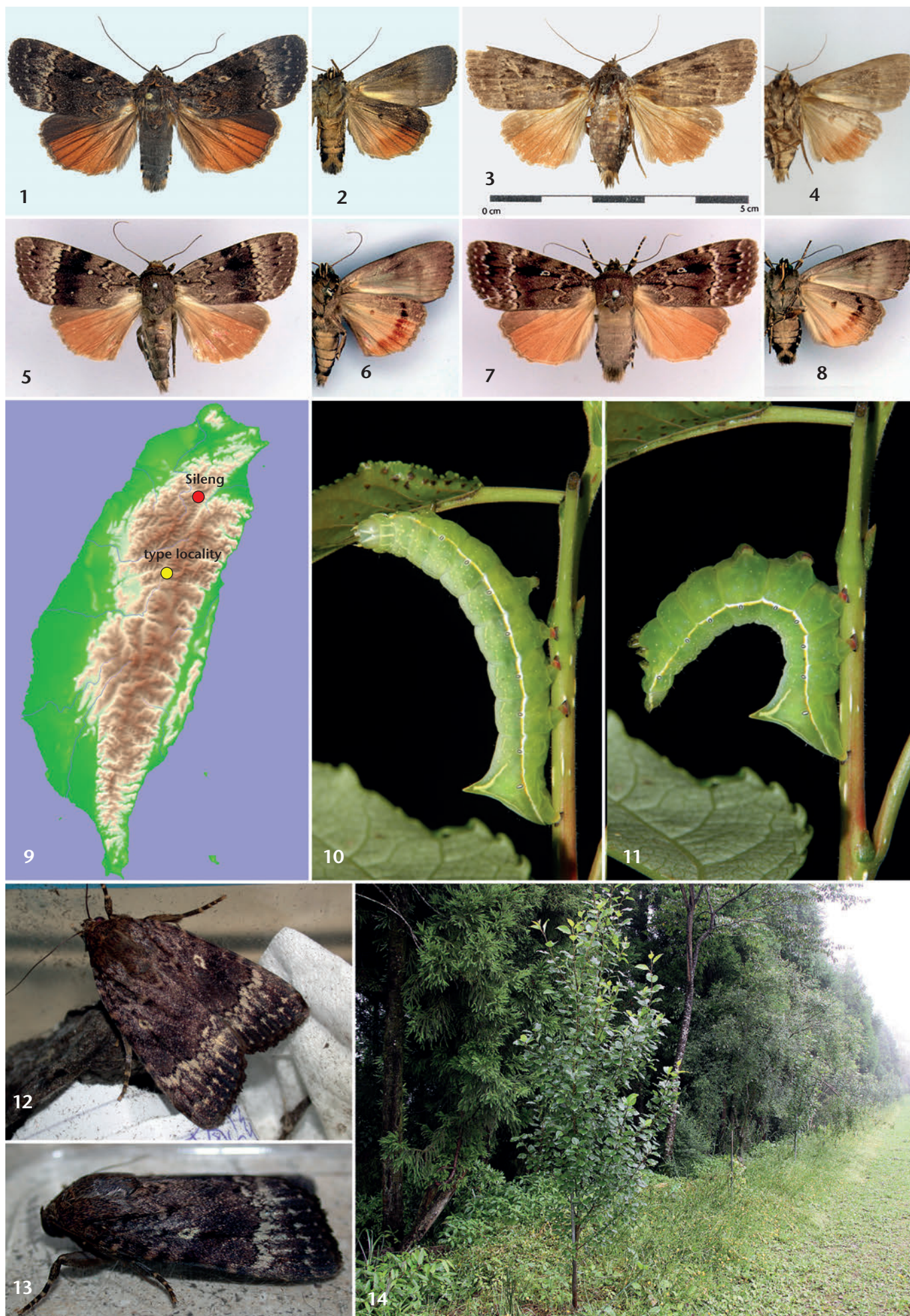
The genus *Amphipyra* OCHSENHEIMER, 1816

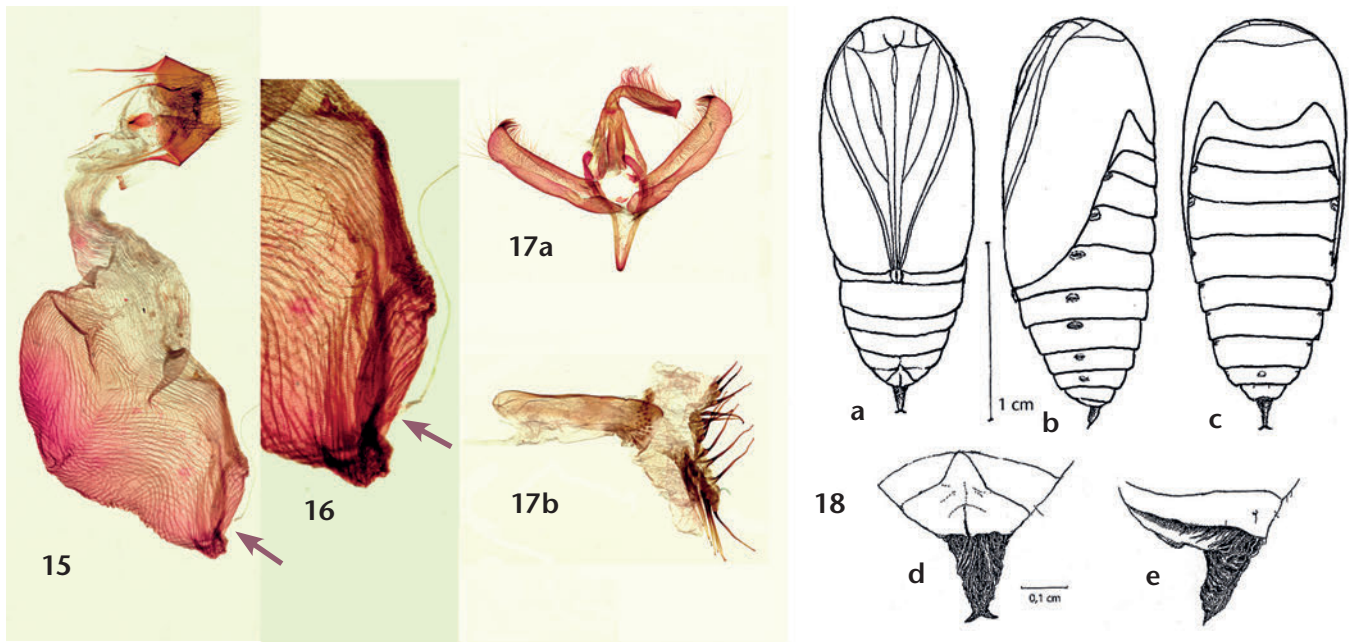
OCHSENHEIMER (1816) erected the genus *Amphipyra*, including 7 species, and *Phalaena tragopoginis* CLERCK, 1759 was subsequently selected as its type-species by DUPONCHEL (1829).

The genus now contains 49 species in the Palearctic region (FIBIGER & HACKER 2007). A few more species are known from North America (LAFONTAINE & SCHMIDT 2010), Africa (HACKER 2001, 2004) and from the Oriental Region (WARREN 1912–1938). Some new species were recently described from Central Asia and also from East and Far East Asia (OWADA 1988, HACKER 1992, 2001, 2004, AHN et al. 1996, HREBLAY & RONKAY 1997, 1998, HREBLEY et al. 1999, GYULAI & RONKAY 2008). In the last decades, new species have been described from the Indian and Indo-Chinese regions (Nepal to Thailand) (e.g., OWADA 1988, HREBLAY & RONKAY 1997, 1998, HREBLAY et al. 1999). In Europe, 10 *Amphipyra* species are known in total (KARSHOLT & RAZOWSKI 1996, FIBIGER & HACKER 2007). FUNAKOSHI (1992, 1994a, 1994b) published about the egg, larval and pupal morphology as well as biology of the Japanese *Amphipyra* species. *Amphipyra* was long treated as the type genus of the large and polyphyletic subfamily Amphipyrinae, but it is now known to be an isolated genus within the triline Noctuidae, and the subfamily is now restricted to a few genera only (e.g. SPEIDEL et al. 1996, KRISTENSEN et al. 2007, ZAHIRI et al. 2010).

The species-group of *A. pyramidea* is represented in Europe only by two species: *A. pyramidea* (LINNAEUS, 1758) and *A. berbera* RUNGS, 1949 (e.g., KOCH 1984, SKOU 1991, EBERT 1997), the former species being common and the latter scarcely recorded. Much has been published about the identification, discrimination, distribution and biology of these two species (e.g. URBAHN 1968, 1969a, 1969b, EBERT 1997, REZBANYAI-RESER 1998, KAWAKAMI & SUGI 2000, FIBIGER & HACKER 2007). *Amphipyra pyramidea* is also recorded from East Asia (INOUE et al. 1982), where it was referred to as subspecies *obscura* OBERTHÜR, 1880 of *A. pyramidea*, which is now regarded as a synonym of the nominotypical subspecies (FIBIGER & HACKER 2007). FLETCHER (1968) discussed the species and subspecies of *A. pyramidea*, *A. berbera* and *A. monolitha* GUENÉE, 1852. This paper, as the initial and still most important paper on the group in question, was supplemented for East Asia by OWADA (1996).

¹ Contribution to moths of Taiwan 6 (Contribution to moths of Taiwan 5: BUCHSBAUM, U., & CHEN, M.-Y. [2012], A new *Terthreutis* MEYRICK, 1918 species from Taiwan (Lepidoptera, Tortricidae). – Entomofauna, Anselden, 34 (26): 349–356).





Figs. 1–4: *Amphipyra meifengensis* sp. n. — **Figs. 1–2:** holotype ♀, upper- (Fig. 1) and underside (Fig. 2, mirrored to show the nail-like pattern better). **Figs. 3–4:** paratype ♂, upper- (Fig. 1) and underside (Fig. 2) (photo: National Museum of Natural Science, Taiwan). — **Fig. 5–6:** *A. monolitha*, upper- (Fig. 5) and underside (Fig. 6). **Fig. 7–8:** *A. pyramidea*, upper- (Fig. 7) and underside (Fig. 8). — **Fig. 9:** Map with the localities of *A. meifengensis* sp. n. (typical locality: yellow, other locality: red) (map created with Map Creator 2). — **Figs. 10–4:** *Amphipyra meifengensis* sp. n. — **Figs. 10–11:** holotype larva collected at the type locality Meifeng. **Fig. 12–13:** Emerged ♀ holotype, alive. **Fig. 14:** Collecting site and type locality of *A. meifengensis* sp. n. with the *Populus* tree as foodplant (photos: Hsin-Hsiung LIN). **Fig. 15–16:** holotype, ♀ genitalia (Fig. 15) and stronger magnification showing the origin of ductus seminalis, see arrows (Fig. 16). **Fig. 17:** paratype, ♂ genitalia (a); b = phallus. **Figs. 18a–e:** pupa and pupal cremaster in detail (drawing: Mei-Yu CHEN).

Methods and locality

The larva of the new species (Figs. 10–11) was found in Meifeng (Nantou Co., Taiwan), in the Hehuan Mountains at about 2100 m (24°5'13" N, 121°10'36" E) on 24. v. 2011. The foodplant, an introduced species of *Populus* (Salicaceae), showed traces of frass. The larva was placed in a plastic rearing box with tissue paper, some soil and *Populus* leaves. The nearly mature larva hardly fed and pupated a few days later, after burrowing into the soil. The pupal stage lasted from 26.–28. v. to 2. vii. 2011, about 5 weeks. The imago emerged at night of 2./3. vii. 2011.

The locality Meifeng is also known as the Meifeng Highland Experimental Farm of the College of Bio-Resources and Agriculture of the National Taiwan University. The locality is surrounded by natural mountain forest and open areas with dry meadows (Fig. 14).

Systematics

Amphipyra meifengensis sp. n.

(Figs. 1–4, 10–18.)

Holotype: ♀, Central Taiwan, near Puli, Nantou Co., Meifeng, ca. 2100 m NN, 24°5'19" N, 121°10'26" E, e.l. 24. v. 2011, leg. Mei-Yu CHEN, genitalia slide 56370 (M.-Y. CHEN), BC ZSM Lep 56370. In National Museum of Natural Science Taiwan, Taichung.

Paratypes (2 ♂♂): 1 ♂, Taiwan, Nantou Xian, Nantou Co., Meifeng, 22. vi. 1984, B.-S. CHANG, genitalia slide 56374 (M.-Y. CHEN), BC ZSM Lep 56374. 1 ♂, Taiwan, Taoyuan Xian, Taoyuan Co., Sileng, 22. xi. 1982, B.-S. CHANG, genitalia slide 56375 (M.-Y. CHEN), BC ZSM Lep 56375. Both in National Museum of Natural Science Taiwan, Taichung.

Etymology: The species is named after the collecting site Meifeng (Nantou Co.) in Central Taiwan. The locality is well known from our earlier Lepidoptera studies (e.g., BUCHSBAUM & MILLER 2002, MEY & SPEIDEL 2003, BUCHSBAUM 2006, BUCHSBAUM et al. 2006, CHEN 2011) and is famous for its high biodiversity (e.g., REICHHOLF 2003).

Description

Forewing length 23 mm, wingspan 54 mm (holotype ♀), forewing length of ♂ paratypes 25 mm, wingspan 56 mm. Head, thorax and abdomen dark brown, with dark yellowish orange scales. Subterminal fascia white, with black tips towards the base. Subterminal fascia and post-medial fascia fused at dorsal margin close to inner angle. Antemedial fascia diffuse. Orbicular stigma clearly white, rounded, with black dot. Hindwing orange brown with darker brownish apex. The ground-colour of the forewing underside is almost entirely dark brown, grayish yellow only at dorsal margin from basis to apex. Hindwing underside fuscous brown at costal margin, below costal margin orange coloured from base to postmedial fascia; a clearly marked nail-like discal spot with black extension-line towards basis is distinctive (see Fig. 2).

♀ genitalia (Figs. 15–16): Different from all other known *Amphipyra* species. Ductus bursae wide, papillae anales short, rounded, wide, compact, squat. Corpus bursae rounded, without clear signum, with peak-like end. Ductus seminalis arises from the anterior end of the corpus.

♂ genitalia (Fig. 17): Principally identical to all other species of the group of *A. pyramidea* (OWADA 1996). Uncus well developed, distal part swollen, with blunt

end. Valva simple, approximately parallel-sided, slightly curved and tapering in apical portion. Phallus with the vesica furnished with 19 mostly slender, long cornuti, attached at terminal end, and very small spicules at the vesica base. The number of cornuti was identical in the 2 ♂♂ dissected, but more dissections would be required to establish their range.

Differential diagnosis: *A. horiei* OWADA, 1996 has a large white subterminal fascia and a small white orbicular stigma without black dot inside, and the subterminal fascia ends in a white apical streak at costa. *A. monolitha* is also similar, larger, darker brownish black from subterminal fascia to middle of forewing. Ground-colour of forewing darker, that of the hindwing also darker with a more diffuse antemedial fascia. The underside of *A. meifengensis* sp. n. is unique in the whole species complex of *A. pyramidea*, darker and with more pronounced markings, with nail-like discal spot. Male genitalia: The numbers of cornuti given are 10–13 for *A. pyramidea* (FIBIGER & HACKER 2007, OWADA 1996), 7–17 for *A. horiei* (OWADA 1996), 11 in a figure of *A. monolitha surnia* (OWADA 1996), and 34–36 for *A. berbera* (FIBIGER & HACKER 2007). Thus, the number of long cornuti of *A. meifengensis* sp. n. is apparently outside the range of the related species. Female genitalia: Ductus bursae in the related species narrower and longer. The papillae anales of the related *Amphipyra* species are small, narrow and elongate. Ductus seminalis originates from the middle of corpus bursae in *A. pyramidea*. The ♀ genitalia are better usable than the ♂ genitalia for discrimination of species of the group of *A. pyramidea*, with several diagnostic features.

Larva

(Figs. 10, 11.)

Typical *pyramidea*-group larva with a horn at end of abdomen. Ground-colour pale green. Head and first thoracic segment with two white lateral lines. Three bright yellow lines dorsally on first thoracic segment. Dorsal line bright yellow, with points on the line. Lateral white line from thorax to last segment with yellow upper border. On first thoracic and from first to eighth abdominal segment with large white black-bordered spiracles in the yellow border. Bright yellow angle in the terminal horned segment. Ventral prolegs distally red. No other *Amphipyra* species is known with such a colouration of the prolegs. In *A. monolitha*, the dorsal line is darker green and there is no yellow angled subdorsal line on the terminal segment.

Food plant: An introduced species of *Populus*.

Pupa

(Figs. 18a–18e.)

Length: 24 mm (exuvia after emergence of the moth). Dark brown to blackish. Frontal structure indistinct. Eyes, labial palps, and legs visible. Forewing structure and veins also visible. Wings cover 4 segments. Cremas-

ter length: 1.5 mm, acuminate with two horn-like spines which are large, rounded, acuminate. The pupa is different from all other species of the *A. pyramidea*-species complex in cremaster structure and in the shape of the horn-like spines. In *A. monolitha*, the cremaster is conical and the horn-like spines are thinner and longer, with different structure. In *A. berbera*, the cremaster is slender with very thin and longer horn-like spines. In *A. pyramidea*, the cremaster is thinner and slender, with short, acuminate horn-like spines with small hooks (see FUNAKOSHI 1994a for the Japanese species and PATOČKA 1995 for the European species *A. pyramidea* and *A. berbera*).

DNA analyses

The following sequences were obtained for the COI gene for the related *Amphipyra* species *A. meifengensis* sp. n., *A. pyramidea* and *A. berbera*, see Table 1. No data are so far available for *A. monolitha* and *A. horiei* which do, however, morphologically not so closely resemble *A. meifengensis* sp. n.

Using Maximum Likelihood or Minimum Evolution methods for evaluation of the COI gene nucleotide sequences results in quite similar trees. The high bootstrap-values for the individual species show that they are quite stable. Astonishingly, *Amphipyra perflua* is shown to belong within the *pyramidea*-group using both methods (Figs. 19a, b), a result not expected by the study of the external appearance. *A. perflua* is indicated as a sister-species of *A. berbera* + *A. meifengensis*, and *A. pyramidea* is the sister-species to this complex. The position of *A. perflua* is identical, when Minimum Evolution method is used for evaluation (Fig. 19b). The Neighbor Joining (NJ) tree (Fig. 19c) received by BOLD, however, shows a different result. It indicates *Amphipyra pyramidea* as immediate neighbour of *A. berbera* + *A. meifengensis*. The Maximum Likelihood tree probably reflects phylogenetic relationship quite well, but is not in accordance with the NJ-tree and external appearance of the species concerning the position of *A. perflua*. It seems, however, to be well substantiated by generally high bootstrap-values (compare Figs. 19a–c).

Discussion

The new species belongs to the group of *A. pyramidea*. This is a group of species superficially very similar to the brown European *A. pyramidea* with laterally flattened uncus, with a broad, blunt end which is terminally acute on its ventral side. The valvae have almost parallel costal and ventral margins and are rounded only distally. The group of *A. pyramidea* in its narrow sense is represented in the region studied by the closely related trans-palaearctic species *A. pyramidea* (OWADA 1996, FIBIGER & HACKER 2007) which also occurs in North and South Korea and Japan and has also been reported from Taiwan (OWADA 1996). Moreover, *A. monolitha* is also found in Taiwan. It is generally larger than *A. pyramidea* and inhabits subtropical areas at lower elevations,

Table 1: Data of the specimens used for the mtDNA sequence analyses. — Abbreviations: GBAC = GenBank Access Code; HT = holotype; PT = paratype; SL = Sequence Length (data from BOLD) in bp [= base pairs]; — = GBAC not yet available. Depositions: NMNST = National Museum of Natural Science Taiwan, Taichung; TLMF = Tiroler Landesmuseum Ferdinandeum, Innsbruck, Austria; ZSM = Zoologische Staatssammlung München [Munich], Germany.

Species	Sample-ID	Process-ID	GBAC	SL [bp]	Sex	Deposition	Locality of origin
<i>A. perflua</i>	BC ZSM Lep 28285	FBLMV 305-09	HQ955398	636 (0n)	♂	ZSM	Germany, Bavaria
<i>A. perflua</i>	BC ZSM Lep 31793	GWORA2536-09	HQ957221	658 (0n)	♂	ZSM	Germany, Bavaria
<i>A. perflua</i>	BC ZSM Lep 21812	GWOR482-09	IF415464	658 (0n)	♂	ZSM	Germany, Bavaria
<i>A. perflua</i>	BC ZSM Lep 21229	GWOR3945-09	IF415465	658 (0n)	♂	ZSM	Germany, Bavaria
<i>A. pyramidea</i>	BC ZSM Lep 29058	FBLMW128-0	HQ563412	658 (0n)	♂	ZSM	Germany, Bavaria
<i>A. pyramidea</i>	BC ZSM Lep 21825	GGWORK485-09	IF41567	658 (0n)	♂	ZSM	Germany, Bavaria
<i>A. pyramidea</i>	BC ZSM Lep 28284	FBLMV304-09	GU707332	658 (0n)	♀	ZSM	Germany, Bavaria
<i>A. pyramidea</i>	BC ZSM Lep 31791	GWORA2534-09	HQ957220	658 (0n)	♂	ZSM	Germany, Bavaria
<i>A. pyramidea</i>	TLMF Lep 02610	PHLACS575-10	IF8601043	658 (0n)	?	TLMF	Italy, South Tyrol
<i>A. pyramidea</i>	BC ZSM Lep 28083	FBLMV103-09	HQ563350	658 (0n)	♂	ZSM	Germany, Bavaria
<i>A. pyramidea</i>	BC ZSM Lep 21816	GWOR486-09	IF415466	618 (0n)	♂	ZSM	Germany, Bavaria
<i>A. berbera</i>	BC ZSM Lep 29056	FBLMW126-10	HQ563410	658 (0n)	♀	ZSM	Germany, Bavaria
<i>A. berbera</i>	BC ZSM Lep 28084	FBLMV104-09	HQ563351	658 (0n)	♂	ZSM	Germany, Bavaria
<i>A. berbera</i>	BC ZSM Lep 31792	GWORA2535-09	HM393236	631 (0n)	♂	ZSM	Germany, Bavaria
<i>A. berbera</i>	BC ZSM Lep 27055	FBLMU405-09	GU707125	658 (0n)	♂	ZSM	Germany, Bavaria
<i>A. meifengensis</i> sp. n. (PT)	BC ZSM Lep 56374	GWOSY463-11	—	658 (0n)	♂	NMNST	Taiwan, Nantou Xian
<i>A. meifengensis</i> sp. n. (HT)	BC ZSM Lep 56370	GWOSY459-11	—	658 (0n)	♀	NMNST	Taiwan, Nantou Xian
<i>A. meifengensis</i> sp. n. (PT)	BC ZAM Lep 56375	GWOSY464-11	—	407 (0n)	♂	NMNST	Taiwan, Taoyuan Xian
<i>A. tragopoginis</i>	BC ZSM Lep 54546	GWOSN915-11	—	658 (0n)	♀	ZSM	Germany, Bavaria
<i>A. tragopoginis</i>	04HBL007156	XAD156-04	GU438736	586 (0n)	?	not indicated	Canada, Ontario
<i>A. tragopoginis</i>	moth2637_02	PHMO343-03	GU094420	639 (1n)	?	not indicated	Canada, Ontario
<i>A. tragopoginis</i>	moth1663_02	PHMO276-03	GU094419	639 (0n)	?	not indicated	Canada, Ontario
<i>A. tragopoginis</i>	BC ZSM Lep 22297	GWORL395-09	GU68687	658 (0n)	♂	ZSM	Germany, Bavaria
<i>A. cinnamomea</i>	BC ZSM Lep 57007	GWOSQ526-11	—	658 (0n)	♂	ZSM	Switzerland

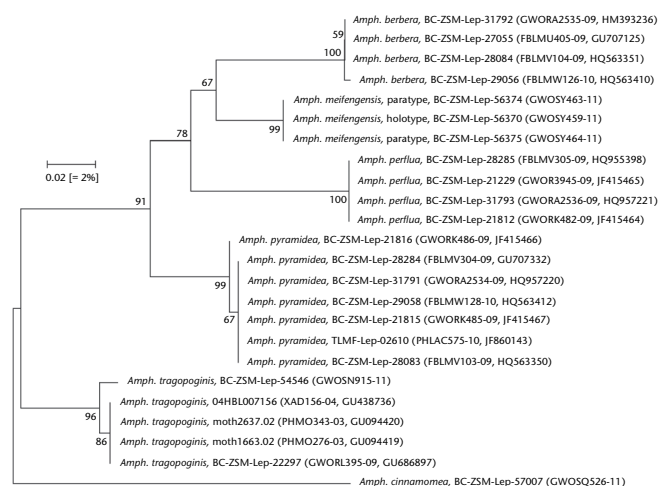
whereas *A. pyramidea* inhabits higher elevations (OWADA 1996). A further species, *A. horiei* OWADA, 1996 (OWADA 1996), was described from Amami-Oshima in the Japanese Ryukyu archipelago, where it is probably endemic. It has not been recorded from Taiwan. The ♂ genitalia provide no reliable characters (possibly except the number of cornuti) to separate these species, but *A. pyramidea* and *A. monolitha* can be readily discriminated by the ♀ genitalia (OWADA 1996), and those of *A. meifengensis* sp. n. also are distinctive. The shape of the corpus bursae is different in virgin females and those who have copulated, so this character is difficult to use, but the origin of the ductus seminalis is clearly different in these species. In *A. pyramidea*, the ductus seminalis arises from the middle of the corpus whereas it arises from the anterior end in *A. monolitha* (OWADA 1996), as in *A. meifengensis*. Based on this difference, a female of *A. pyramidea* (with ductus seminalis from about middle of corpus) is recorded from Tayuling (Taiwan) by OWADA (1996: 134, fig. 19). Though the two species have similar female genitalia, *A. meifengensis* can be separated from *A. monolitha* by the very different COI base sequences and different wing pattern.

It is a rather subjective decision which geographical subspecies of *A. pyramidea* are regarded as valid and which as unnecessary and synonymous. The mediterranean *A. pyramidea cuprior* FLETCHER, 1968 was synonymized with the nominotypical subspecies (FIBIGER

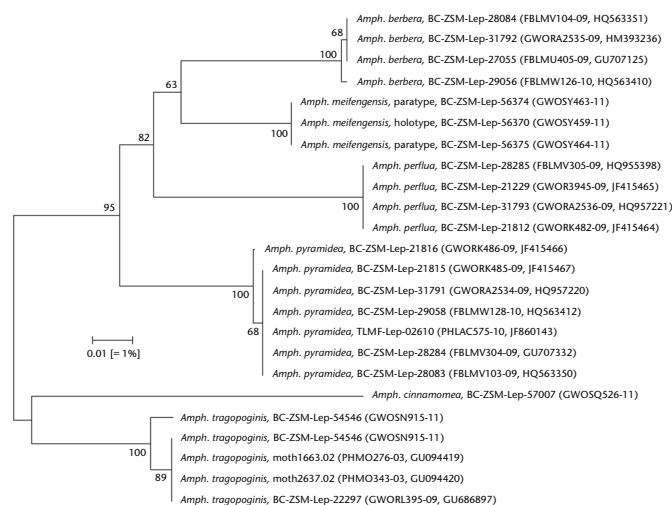
& HACKER 2007); *A. pyramidea obscura* OBERTHÜR, 1880 from southeast Siberia, northeast China and the Kuriles is also very similar to the European population and was treated as synonymous with the nominotypical subspecies (FIBIGER & HACKER 2007), but *A. pyramidea yama* SWINHOE, 1918 from Japan and Korea can be discriminated from the latter according to OWADA (1996). The taxon *A. suryai* YOSHIMOTO, 1994 from Nepal is controversial, sometimes treated as a separate species (YOSHIMOTO 1994) and sometimes as a subspecies of *A. pyramidea* (OWADA 1996). It is difficult to decide about specific or subspecific status of closely related taxa in case of allopatric distribution, and so the status of all these so-called *A. pyramidea* subspecies may be doubtful. However, *A. meifengensis* sp. n. has an entirely different DNA barcode which clearly indicates specific rank, and larval data and the structure of the ♀ genitalia support this view.

Representation of *Amphipyra* species in Taiwan and temperate East Asia

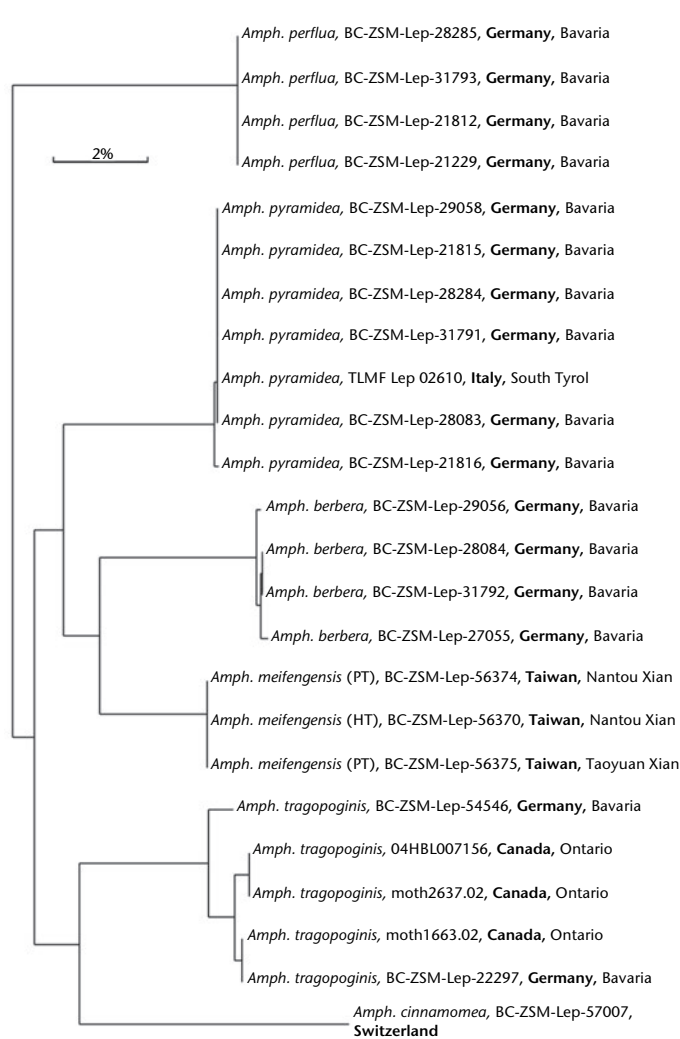
Most species of this Palearctic genus occur at higher altitudes in Taiwan. Only *A. monolitha* is recorded from lower altitude in subtropical areas of the warm temperate zone, whereas *A. pyramidea* is distributed in the cold temperate zone in Japan and Taiwan according to OWADA (1996). Also the other species of *Amphipyra* recorded from this area are only found above 2000 m elevation:



19a



19b



19c

Figs. 19a–c: Mitochondrial DNA COI-barcode trees with *A. meifengensis* sp. n. In Figs. 19a + b, codon positions included were 1st + 2nd + 3rd + Non-coding. All positions containing gaps and missing data were eliminated. There were a total of 376 positions (= base pairs) in the final dataset. Evolutionary analyses were conducted in MEGA5 (TAMURA et al. 2011), the bootstrap consensus tree inferred from 1000 replicates is taken to represent the evolutionary history of the taxa analyzed (FELSENSTEIN 1985). The percentage of replicate trees in which the associated taxa clustered together in the bootstrap test are shown next to the branches. Branches corresponding to partitions reproduced in less than 50% bootstrap replicates are collapsed. The analysis involved 24 nucleotide sequences (= specimens). Compare Table 1 for details of the specimens. — **Fig. 19a:** Molecular phylogenetic analysis by **Maximum Likelihood** method, based on the Data specific model (NEI & KUMAR 2000). Initial tree(s) for the heuristic search were obtained automatically as follows. When the number of common sites was < 100 or less than one fourth of the total number of sites, the maximum parsimony method was used; otherwise BIONJ method with MCL distance matrix was used. A discrete Gamma distribution was used to model evolutionary rate differences among sites (5 categories [+ G, parameter = 0.7122]). The rate variation model allowed for some sites to be evolutionarily invariable ([+ I], 66.6470% sites). The tree is drawn to scale, with branch lengths measured in the number of substitutions per site. — **Fig. 19b:** The evolutionary history was inferred using the **Minimum Evolution** method (RZHETSKY & NEI 1992). The tree is drawn to scale, with branch lengths in the same units as those of the evolutionary distances used to infer the phylogenetic tree. The evolutionary distances were computed using the Maximum Composite Likelihood method (TAMURA et al. 2004) and are in the units of the number of base substitutions per site. The rate variation among sites was modeled with a gamma distribution (shape parameter = 3). The differences in the composition bias among sequences were considered in evolutionary comparisons (TAMURA & KUMAR 2002). The ME tree was searched using the Close-Neighbor-Interchange (CNI) algorithm (NEI & KUMAR 2000) at a search level of 0. The Neighbor-joining algorithm (SAITOU & NEI 1987) was used to generate the initial tree. — **Fig. 19c:** **Neighbor Joining** tree, as downloaded from the BOLD website.

- *Amphipyra schrenckii* MÉNÉTRIÉS, 1859: below 2200 m
- *Amphipyra shyrshana* CHANG, 1991: above 3200 m
- *Amphipyra fuscusa* CHANG, 1991: above 3200 m

FUNAKOSHI (1994) listed all the known foodplants for the generally polyphagous species of *Amphipyra* from Japan and East Asia: *Quercus* spp. (Fagaceae), *Celtis sinensis* (Ulmaceae), *Eurya japonica* and *Cleyera japonica* (Theaceae), *Prunus* spp. (Rosaceae), *Acer palmatum* (Aceraceae), *Elaeagnus umbellata* (Elaeagnaceae), and *Ligustrum japonica* (Oleaceae) for *A. monolitha* and *Quer-*

cus spp. (Fagaceae), *Malus* spp., *Prunus* spp. and *Pyrus serotina* (Rosaceae), *Vitis vinifera* (Vitaceae) and *Syringa reticulata* (Oleaceae) for *A. pyramidea*. *Populus* is not recorded as a foodplant from Japan. The present record is the first for a *Populus* sp. as foodplant for the genus *Amphipyra* in Asia, though it has been reported for *A. pyramidea* from Europe (e.g., EBERT 1997).

Including *A. meifengensis* sp. n., 10 species of the genus *Amphipyra* OCHSENHEIMER, 1816 are recorded from Taiwan:

- *A. monolitha* GUENÉE, 1852
- *A. pyramidea* (LINNAEUS, 1758) (also recorded as *A. acheron* DRAUDT, 1950 by CHANG 1991 according to OWADA 1996)
- *A. schrenckii* MÉNÉTRIÉS, 1859
- *A. fuscata* CHANG, 1991
- *A. shyrshana* CHANG 1991
- *A. surnia* FELDER & ROGENHOFER, 1874
- *A. averna* HREBLAY & RONKAY, 1997
- *A. formosana* HREBLAY & RONKAY, 1998
- *A. deletaiwana* HREBLAY & RONKAY, 1998
- *A. meifengensis* sp. n.

Acknowledgements

Colleagues from the Taichung Museum: Meiling CHAN, Ming-Luen JENG and Yen-Lin CHEN, kindly sent abdomina and provided photos of additional *Amphipyra* material from the National Museum of Natural Science, Taichung, for our study. Many thanks to all former colleagues and friends at Meifeng. Special thanks to Hsin-Hsiung LIN (Meifeng Highland Experimental Farm) for providing photos of the collecting site of the new species. Furthermore, we kindly thank Keh-miin CHEN for his ongoing cooperation and generous support for the project. Dr. Marianne HORAK (CSIRO, Australia) kindly corrected the English and gave valuable contributions to improve our manuscript considerably. The molecular work (COI barcoding) of the *Amphipyra* material was funded by NSERC and Genome Canada through grants to Paul D. N. HEBERT at the Canadian Centre for DNA Barcoding based at the Biodiversity Institute of Ontario at the University of Guelph, Ontario, Canada. Dr. Wolfgang A. NÄSSIG (Frankfurt am Main) edited our manuscript in the usual careful manner and contributed by valuable suggestions especially concerning the DNA analysis.

References

- AHN, S.-B., KONONENKO, V. S., & WEON, K.-J. (1996): Newly recorded and rarely known species of Noctuidae (Lepidoptera) from the Korean Peninsula. — Korean Journal of Applied Entomology, Seoul, 35 (4): 287–296.
- BUCHSBAUM, U. (2006): Ergebnisse entomologischer Reisen nach Taiwan. — Mitteilungen des Thüringer Entomologenverbandes e. V., Gotha, 13 (1): 36–48.
- , & CHEN, M.-Y. (2010): *Camptoloma quimeiae* sp. n., a new Camptolominae species from Taiwan (Lepidoptera, Noctuidae). — Entomofauna, Ansfelden, 31 (6): 49–56.
- , & — (2012): A new *Terthreutis* MEYRICK, 1918 species from Taiwan (Lepidoptera, Tortricidae). — Entomofauna, Ansfelden 34 (26): 349–356.
- , —, & ZOLOTUHN, V. V. (2006): *Thyris alex* sp. n. — a new Thyrididae species from Taiwan and new record of this genus and the subfamily for Taiwan, with notes to biology, distribution and DNA analyses and notes on a system of the genus (Insecta: Lepidoptera). — Journal of the Zoological Society Wallacea, München, 2: 54–62.
- , & MILLER, M. A. (2002): *Leucoblepsis taiwanensis* sp. n. a new species of Drepanidae from Taiwan (Insecta: Lepidoptera). — Formosan Entomologist, Taipei, 22 (2): 101–114.
- CHANG B. S. (1991): Illustrations of moths in Taiwan 5. Noctuidae. — Taipei (Taiwan Museum), 366 pp. [in Chinese].
- CHEN, M.-Y. (2010): Tracing moths in the starry night. Handbook of moth observation in Mei-Feng. — Meifeng Highland Experimental Farm, National Taiwan University, Taipei, 240 pp.
- DUPONCHEL, P. A. J. (1829): Histoire naturelle des Lépidoptères, ou papillons de France, vol. 7 (2). — Paris (Mequignon-Marvis), 507 pp., pls. 133–170.
- EBERT, G. (ed.) (1997): Die Schmetterlinge Baden-Württembergs. 6, Nachfalter IV. — Eugen Ulmer, Stuttgart. 622 pp.
- FELSENSTEIN J. (1985): Confidence limits on phylogenies: An approach using the bootstrap. — Evolution, New York, 39 (4): 783–791.
- FIBIGER, M., & HACKER, H. H. (2007): Noctuidae Europaeae Vol. 9, Amphipyridae, Condicinae, Eriopinae, Xyleninae (part). — Sorø (Entomological Press), 410 pp.
- FLETCHER, D. S. (1968): *Amphipyra pramidea* (LINNAEUS) and *A. berbera* RUNGS (Lep., Noctuidae), two species confused. — Entomologists' Gazette, London, 19 (2): 91–106.
- FUNAKOSHI, S. (1992): Two colour forms of *Amphipyra monolitha* larvae (Noctuidae) presumably representing separate species. — Japan Heterocerists' Journal, Tokyo, 167: 301–303.
- (1994a): Pupae of Japanese *Amphipyra* moths (Lepidoptera, Noctuidae). — Tyo to Ga, Osaka, 45 (3): 203–210.
- (1994b): Behaviour and food plants of the *Amphipyra* larvae (Lepidoptera; Noctuidae). — Tyo to Ga, Osaka, 44 (4): 249–257.
- (2006): The relationship between the geostationary posture and the dorsal projection of the eight abdominal segment of the *Amphipyra* larvae (Lepidoptera, Noctuidae). — Yadoriga, Kyoto, 210: 54–57.
- GYULAI, P., & RONKAY, L. (2008): New Noctuidae species from Asia (Lepidoptera). — Folia Entomologica Hungarica, Budapest, 69: 201–212.
- HACKER, H. H. (1992): Neue Noctuidae-Arten aus Nordthailand. — Esperiana, Buchreihe zur Entomologie, Schwanfeld, 3: 185–191.
- (2001): Fauna of the Nolidae and Noctuidae of the Levante with descriptions and taxonomical notes (Lepidoptera, Noctuoidea). — Esperiana, Buchreihe zur Entomologie, Schwanfeld, 8: 7–398.
- (2004): 22. Nolidae and Noctuidae (excluding Catocalinae: Audeini and Tachosini) (Lepidoptera). — Pp. 261–304 in: MEY, W. (ed.), The Lepidoptera of the Brandberg Massif in Namibia, part 1. — Esperiana Memoir, Buchreihe zur Entomologie, Schwanfeld, 1: 333 pp.
- HREBLAY, M., PEREGOVITS, L., & RONKAY, L. (1999): New genera and species of Noctuidae from Vietnam, Thailand and Nepal (Lepidoptera). — Acta Zoologica Academiae Scientiarum Hungaricae, Budapest, 45 (1): 1–96.
- , & RONKAY, L. (1997): New Noctuidae (Lepidoptera) species from Taiwan and the adjacent areas. — Acta Zoologica Academiae Scientiarum Hungaricae, Budapest, 43 (1): 21–81.
- , & — (1998): Noctuidae from Nepal. — Pp. 117–310, pls. 144–157 in: HARUTA, T. (ed.), Moths of Nepal, 5. — Tinea, Tokyo, 15, Supplement 1: xvi + 314 + [1] pp. + pls. 129–160.
- INOUE, H., SUGI, S., KUROKO, H., MORIUTI, S., & KAWABE, A. (1982): Moths of Japan, 2 vols. — Tokyo (Kodansha), 1: 966 pp.; 2: 392 pls. + 552 pp.
- KARSHOLT, O., & RAZOWSKY, J. (eds.) (1996): The Lepidoptera of Europe. A distributional checklist. — Steenstrup (Apollo Books), 380 pp.

- KAWAKAMI, Y., & SUGI, S. (2000): *Amphipyra pyramidea* (LINNAEUS (Noctuidae, Amphipyrinae) and allies from western Honshu and Shikoku. — Japan Heterocerists' Journal, Tokyo, **208**: 148–150.
- KOCH, M. (1984): Wir bestimmen Schmetterlinge. — Leipzig, Radebeul (Neumann), 792 pp.
- KRISTENSEN, N. P., SCOBLE, M. J., & KARLSHOLT, O. (2007): Lepidoptera phylogeny and systematics: the state of inventoring moths and butterfly diversity. — Zootaxa, Auckland, **1668**: 699–747.
- LAFONTAINE, J. D., & SCHMIDT, B. C. (2010): Annotated checklist of the Noctuoidea (Insecta, Lepidoptera) of North America north of Mexico. — ZooKeys, Sofia, **40**: 1–239.
- MEY, W., & SPEIDEL, W. (2003): Lepidoptera diversity at high and low altitudes in Taiwan and Luzon — a comparison. — Journal of the Zoological Society Wallacea, München, **1**: 29–42.
- NEI, M., & KUMAR, S. (2000): Molecular evolution and phylogenetics. — New York (Oxford Univ. Pr.), 348 pp.
- OCHSENHEIMER, F. (1816): Die Schmetterlinge von Europa **4**: x + 224 pp. — Leipzig (Fleischer).
- OWADA, M. (1988): A new noctuid moth of the genus *Amphipyra* (Lepidoptera) from Amami-Oshima, the central Ryukyus. — Bulletin of the National Science Museum, Tokyo, (A) **14**: 91–95.
- (1996): Notes on the moths of the *Amphipyra pyramidea* complex (Lepidoptera, Noctuidae) in Japan, with description of a new species. — Memoires of the National Science Museum, Tokyo, **29**: 125–142.
- PATOČKA, J. (1995): Die Puppen der mitteleuropäischen Eulen: Charakteristik und Bestimmungstabelle der Gattungen (Insecta: Lepidoptera: Noctuidae). — Annaalen des Naturhistorischen Museums Wien, **97 B**: 209–254.
- REICHHOLF, J. H. (2003): Melanesia island biogeography. From Alfred R. WALLACE to Robert H. MACARTHUR and beyond: What makes “Wallacea” so unique? — Journal of the Zoological Society, München, **1**: 4–11.
- REZBANYAI-RESER, L. (1998): *Amphipyra berbera svenssoni* FLETCHER, 1968 und ihr Vorkommen in der Schweiz, nebst taxonomischen und systematischen Bemerkungen zur Art (Lepidoptera, Noctuidae). — Atalanta, Markleuthen, **28** (3/4): 291–307.
- RZHETSKY, A., & NEI, M. (1992): A simple method for estimating and testing minimum evolution trees. — Molecular Biology and Evolution, Oxford, **9** (5): 945–967.
- SAITOU, N., & NEI, M. (1987): The neighbor-joining method: A new method for reconstructing phylogenetic trees. — Molecular Biology and Evolution, Oxford, **4** (4): 406–425.
- SCHACHT, W., BUCHSBAUM, U., & CHEN, M.-Y. (2010): Räuberische Calliphoriden attackieren Termiten in Taiwan (Diptera: Calliphoridae/Isoptera: Termitidae). — Entomofauna, Ansfelden, **31** (4): 25–32.
- SCHINTLMEISTER, A. (2003): The Zoogeography of Taiwan's Notodontidae (Lepidoptera). — Journal of the Zoological Society Wallacea, München, **1**: 15–26.
- SKOU, P. (1991): Nordens Ugler. Handbog over de i Danmark, Norge, Sverige, Finland og Island forekommende arter af Herminiidae og Noctuidae (Lepidoptera). — Stenstrup (Apollo Books), 565 pp., 37 pls.
- SPEIDEL, W., & BEHOUNEK, G. (2005): The genus *Wittstrotia* gen. nov. (Lepidoptera, Noctuidae, Eustrotiinae). — Entomofauna, Ansfelden, **26** (23): 393–408.
- , FÄNGER, H., & NAUMANN, C. M. (1996): The phylogeny of the Noctuidae (Lepidoptera). — Systematic Entomology, London, **21**: 219–251.
- TAMURA, K., & KUMAR, S. (2002): Evolutionary distance estimation under heterogeneous substitution pattern among lineages. — Molecular Biology and Evolution, Oxford, **19** (10): 1727–1736.
- , NEI, M., & KUMAR, S. (2004): Prospects for inferring very large phylogenies by using the neighbor-joining method. — Proceedings of the National Academy of Sciences (USA) [PNAS], Washington, **101** (30): 11030–11035.
- , PETERSON, D., PETERSON, N., STECHER, G., NEI, M., & KUMAR, S. (2011): MEGA5: Molecular evolutionary genetics analysis using maximum likelihood, evolutionary distance, and maximum parsimony methods. — Molecular Biology & Evolution, Oxford, **28** (10): 2731–2739.
- URBAHN, E. (1968): *Amphipyra pyramidea* L. und *Amphipyra berbera* RUNGS — zwei schwer unterscheidbare heimische Noctuidenarten. — Entomologische Nachrichten, Dresden, **12** (9): 97–102.
- (1969a): Unterschiede der Jugendstände von *Amphipyra pyramidea* L. und *A. berbera svenssoni* FLETCHER. — Notulae Entomologicae, Helsingfors, **49**: 247–253.
- (1969b): Die Jugendstände von *Amphipyra berbera* ssp. *svenssoni* FLETCHER (Lep., Noctuidae). — Entomologische Berichte, Berlin, **1969**: 133–137.
- WARREN, W. (1912–1938): Eulenartige Nachtfalter. — In: SEITZ, A. (ed.), Die Gross-Schmetterlinge des Indo-Australischen Faunengebietes, vol. **11**. — Stuttgart (Alfred Kern), 496 pp., 56 pls.
- YOSHIMOTO, H. (1994): Noctuidae. — Pp. 95–139, pls. 83–87 in: HARUTA, T. (ed.), Moths of Nepal. Part 3. — Tinea, Tokyo, **14** (Supplement 1): xvii + 171 pp., pls. 65–96.
- ZAHIRI, R., KITCHING, I. J., LAFONTAINE, J. D., MUTANEN, M., KAILA, L., HOLLOWAY, J. D., & WAHLBERG, N. (2010): A new molecular phylogeny offers hope for a stable family level classification of the Noctuoidea (Lepidoptera). — Zoologica Scripta, Oslo, **45**: 158–173.

Received: 19. ix. 2012